FINAL REPORT

The Department of Defense Continuous Learning System for 2012:

An Advanced Distributed Learning Research Assessment

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by

EXECUTIVE SUMMARY

Computer-aided instruction and distance learning are becoming a fact of life for the Department of Defense (DoD). The explosion of computer, telecommunication, and networking technologies is blurring the distinction between training and operational systems, leading to a more holistic concept of military training and education. As computer aided instruction and simulations become more sophisticated, their utility extends from training to performance and mission support. The Navy's Interactive Multisensor Analysis Training (IMAT) system for its Anti-Submarine Warfare forces is an example of this crossover capability. Advances in Advanced Distributed Learning (ADL) technologies will accelerate this trend, providing Service personnel and their civilian counterparts access to continuous learning and with it enhancements in DoD workforce performance.

The Deputy Under Secretary of Defense for Science and Technology (DUSD (S&T)) focus on Cognitive Readiness supports research initiatives to accelerate the development of DoD's ADL capability. Cognitive Readiness emphasizes the importance of the human dimension of war and the potential for advances in cognitive performance to become a revolutionary war-winning capability.

This report supports development of a research agenda to produce a robust ADL capability for DoD at the end of the first decade of the 21st Century. The envisioned end state for this powerful capability provides enhanced learning and practice environments critical to future warfighting success. This report reflects the conclusions of a front-end assessment framing ADL research issues and includes the results of a four-day ADL S&T Workshop held in October 1999.

A front-end assessment and expert review produced a consistent picture of an envisioned end state for a robust ADL capability by the year 2012 (*"ADL in 2012")* and the S&T research necessary to achieve that desired end state. The ADL initiative grew out of the DoD strategy to "harness the power of learning and information technologies to modernize education and training" (DUSD (R), 1999). This effort is currently in the "prototype stage," reflecting a handcrafted approach to development that is too often domain specific. Current ADL successes are typically labor intensive and not transferable from one subject to another. To realize the robust ADL capability envisioned for 2012, DoD must develop a production model approach to ADL development enabling rapid generation and dissemination of tailorable and effective instruction.

This analysis identified four key research areas that address the educational design process from requirements analysis and course development to delivery and assessment. Focused research in these four areas is necessary to achieve the *"ADL in 2012"* vision.

- **Intelligent Computer Aided Instruction (ICAI):** ICAI focuses on the development of an empirical foundation of how individuals and teams develop expertise to guide the selection of ADL instructional alternatives and provide an

accurate assessment to enable appropriate follow-on, remedial instruction, and system improvement.

- **Authoring Tools (AT):** Authoring tools examine the development of tools to quickly and appropriately retrieve and effectively teach digitally coded knowledge and skills.

- **Distributed Simulations (DS):** Distributed simulations look at the problem of generating realistically performing models of individual behavior, virtual team members, adversaries, friendly forces, and non-combatants in a realistic environment across the ADL network.

- **Dynamic Learning Management (DLM):** Dynamic learning management addresses the infrastructure and architecture needed to ensure ADL interoperability and security.

Table 1 represents the critical path items that require immediate additional attention to realize the vision of *"ADL in 2012"*. The designation of these areas for further funding reflects their importance for *"ADL in 2012"* and the relative paucity of leverageable current funding. Progress in understanding human cognition provides a theoretical framework for how to achieve optimal results. Advances in assessment will increase the learning efficiency by enabling instruction tailored to individual learner needs.

Table 1. *"ADL in 2012"* Key Research Areas

***"ADL in 2012":* Key Research Areas**		
Description	**Goals**	**Research Issues**
Assessment Methods for automatically generating unobtrusive, near real time assessment techniques	Develop a comprehensive model linking learner behaviors with learning and outcomes Increase efficiency and validity of assessment generation Tailor assessment generation to individuals and teams Develop cumulative measures of relevant experience	How can comprehensive models and measures of individual and team capabilities and performance be generated? How can valid, unobtrusive near real time assessment from learner interactions with the learning environment be developed? How do we model individual training and experience histories to predict the ease of learning and retention of needed task-specific knowledge and skills? What techniques can we develop for assessing cognitive workload and strategies for mitigating adverse effects of workload?

"ADL in 2012": **Key Research Areas**		
Description	**Goals**	**Research Issues**
Cognitive Theory Understand higher-order cognitive skill development including decision-making, problem-solving, teamwork, metacognition, pattern recognition, critical thinking, and situational awareness	Create principles of distributed instruction based on established models of learning and skill acquisition Develop ADL instructional alternatives built on understanding how individual and team expertise develop	How does expertise evolve in complex, ill-structured environments? What is the role/significance of flexible/adaptive learning in promoting better problem solving and critical thinking? What is the role of cognitive workload in individual, group, and team learning?

Achieving the vision of *"ADL in 2012"* depends on observing, encouraging, and leveraging ongoing work throughout all elements of DoD from military education and training to operational units. This research assessment provides additional direction for researchers in the military, academia, commercial sector, and DoD to follow to achieve the envisioned capability for *"ADL in 2012."*

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FOREWORD

ITT Industries, Systems Division (ITT), performed the work culminating in this report as part of its task "Technical Support for the Cognitive Readiness Focus Area" supporting the Director, Bio Systems, in the Office of the Deputy Under Secretary of Defense for Science and Technology (ODUSD [S&T]). This task is Delivery Order 22 issued under contract N00600-96-D-3132, Decision Support Analysis for the S&T Community, supporting ODUSD (S&T).

This report is a product of an ITT Advanced Distributed Learning Research Assessment and a subsequent expert review. ITT conducted a front-end assessment of current Advanced Distributed Learning (ADL) research to obtain a representative overview of the current state of research and development in ADL-related technologies and provide guidance on which technologies may need greater attention in the future. ADL experts vetted these conclusions during the course of a four-day S&T ADL Workshop in October 1999. This assessment identifies opportunities for DUSD (S&T) to invest in basic, applied, and advanced technology development research in the areas of learning technology, cognitive science, and related fields that will accelerate, direct, and extend the impact of ADL on the military instructional system through 2012.

Section 1 of the assessment provides the context for developing the research agenda to achieve the vision for *"ADL in 2012"* and sets forth an end state for a robust *"ADL in 2012"* capability. As part of this discussion, Section 1 addresses the DUSD (S&T) cognitive readiness initiative and the objective of the report.

Section 2 establishes the parameters of the analysis by defining four research areas for DUSD (S&T) consideration.
Intelligent Computer Aided Instruction
Distributed Simulation
Authoring Tools
Dynamic Learning Management

Section 3 details the identified research areas, synthesizing the front-end assessment and workshop results.

Section 4 examines the role of policy and culture in influencing the achievment of the vision for *"ADL in 2012."* A number of related non-technical issues are noted in this section.

Section 5 summarizes recommendations of this analysis regarding a research agenda to guide investment decisions for achieving the effective anytime, anywhere instructional and practice environments necessary for making the *"ADL in 2012"* vision a reality.

Finally, the appendices (available on the enclosed CD-ROM) provide the background framing the study. Appendices D and E offer an assessment of current DoD S&T ADL-related research and operations and maintenance funding, respectively. Each funding review includes a summary and a searchable collection of relevant programs. Appendix A

contains the briefs and information used to organizationally and technically "set the stage" for the ADL S&T Workshop. Appendix B provides a list of ADL S&T Workshop participants and attendees and the organizations they represented. Selected resources used during the course of the study, including a bibliography and Internet sources, are located in Appendix C.

SECTION 1
INTRODUCTION

1.1 BACKGROUND

1.1.1 Advanced Distributed Learning (ADL) Seeks to Provide the Warfighter with On-Demand Training and Education

The addition of Advanced Distributed Learning (ADL) capabilities to traditional Armed Forces education and training programs provides powerful new tools to establish, improve, and maintain the skills of American soldiers, sailors, airmen, and marines. The emergence of networking and computer technologies enables easier access to distributed education and training resources. ADL empowers "learner centric" education and training, marking a shift from the current classroom and distance teaching philosophy to a model of anytime, anywhere learning. Formal instruction is becoming more effective and less restricted to classroom settings and training events as Service personnel access expanding ADL-compliant content on-demand around the world.

1.1.2 Training and Education are Central Components of Developing Cognitive Readiness in Support of *Joint Vision 2010*

The Deputy Under Secretary of Defense for Science and Technology (DUSD (S&T)) is supporting research initiatives to advance the development of ADL as part of its focus on Cognitive Readiness. ADL based education and training are the first of several factors being examined by DUSD (S&T) (See Figure 2). Cognitive Readiness underscores the importance of the human dimension in war and the understanding that advances in cognitive performance may become a revolutionary war-winning capability. Enhanced mental preparation assumes greater importance in the high tempo warfare envisioned in *Joint Vision 2010*. The ability to gain and use information superiority is critical to shaping and reacting to events on the battlefield and ensuring decision dominance.

Figure 1. DUSD (S&T) Focus on Cognitive Readiness

1.2 STUDY OBJECTIVE: IDENTIFY KEY COMPONENTS FOR A RESEARCH AGENDA FOR ACHIEVING A ROBUST ADL CAPABILITY BY 2012

ADL research initiatives are required to equip the warfighter with superior learning technologies necessary to meet current and future mission requirements. Through the creation of a program of focused research investments, DUSD (S&T) seeks to optimize ongoing research efforts by the Department of Defense (DoD) Services and Agencies. This assessment identifies opportunities for DUSD (S&T) to invest in basic, applied, and advanced technology development research in the areas of learning technology, cognitive science, and related fields that will accelerate, direct, and extend the impact of ADL on the military instructional system through 2012.

SECTION 2
ADL RESEARCH FRONT-END ASSESSMENT

2.1 DUSD (S&T) DIRECTED A FRONT-END ASSESSMENT TO PROVIDE A COMMON BASE OF UNDERSTANDING FOR FUTURE ADL S&T INITIATIVES

A front-end assessment of existing S&T efforts related to ADL was conducted to identify currently funded research as well as to begin to determine the research required to enable optimal implementation of ADL. The study's approach consisted of interviews with subject matter experts in psychology, computer science, artificial intelligence, modeling and simulation, education, and related areas. These experts identified relevant studies and projects for review, provided background, and served as a resource throughout the study. Independent Internet and literature searches were performed to gain an overview of industry, academic, and government ADL research efforts (See Appendix C). This included a focused review of DoD S&T funding relevant to education and training to establish a baseline of current ADL-related research. (See Appendix D and note the caveats pertaining to data.).

2.2 DEFINING THE EVOLVING MILITARY REQUIREMENT FOR TRAINING AND EDUCATION

2.2.1 The Battlefield is Increasingly Fluid and Chaotic

The future of warfare according to *Joint Vision 2010* promises an increasingly lethal battlefield in which commanders can target and kill key enemy assets in real time using satellite-based surveillance systems, precision guided munitions, and computer-based mission planning systems. The frenetic pace of this emerging "hyperwar" is generating increased pressure on commanders and their staffs as they look to keep pace with the explosion of information and the need for rapid decision making (Hoffman, 1994). The ability to collect, analyze, fuse, and disseminate information at the appropriate pace and sequence will separate the victors from the vanquished on an increasingly transparent battlefield.

The US doctrine of maneuver warfare attempts to address the chaos of the battlefield by devolving decision making authority to lower levels closer to the point of decision. This approach places a premium on the ability to act and to react to events more quickly than an opponent can respond. Emerging from this fluid environment is the notion of the "strategic corporal" whose actions may increasingly affect the outcome of single engagements and even entire campaigns (Krulak, 1999). The decision to strafe a suspected Serb motor column during the Kosovo campaign and the resulting political fallout from the civilian casualties inflicted in the attack demonstrates the impact of decisions made by lower ranking personnel and their potential consequences.

2.2.2 Service Personnel Must be Capable of Penetrating the Fog of War

The development of the strategic corporal challenges long held assumptions regarding the development of the prototypical individual required for battlefield success. The ongoing Revolution in Military Affairs suggests a need for a shift in focus in military training and education from relatively rudimentary skills associated with specific techniques and procedures to higher order cognitive skills involving collaboration, reflection, and articulation. The ability to seamlessly conduct operations ranging from military operations other than war to general warfare requires flexible and adaptable personnel. As *Joint Vision 2010* captures, "People are the Armed Forces; at the end of the day, our success, in war or in peace, will rest ultimately on the men and women of the Armed Forces." (*Joint Vision 2010,* 1996)

2.2.3 Real World Constraints Impact the Services' Ability to Train and Educate

A number of factors ranging from competition for recruits to the evolving security environment threaten to outpace the military's ability to provide comprehensive military education and training. Current and forecasted trends in military recruiting point to a shortage of qualified candidates for the Services. With increasing numbers of prospective applicants choosing college and civilian jobs, the Army, Air Force, and Navy are facing a recruitment gap that a Federal advisory commission identified as a potential future military threat (Myers, 1999). The statistics on retention of experienced personnel are no more encouraging. With the exception of the Marine Corps, all the Services failed to meet their retention goals for fiscal year 1999. The Air Force's struggle to keep experienced pilots typifies the problem of maintaining key military occupations at authorized strength. In addition, decisions made to keep experienced service men and women during the early 1990s draw down are being felt as this group approaches retirement age (Tracey, 1999).

The high operational tempo and personnel turnover of today's military results in reduced training and educational opportunities. Students are geographically separated and have limited time to receive necessary instruction. Service personnel stationed in the Persian Gulf, for example, enforcing the sanctions against Iraq are unavailable to attend stateside schools and training. Finally, competition for dollars to achieve desired levels of readiness and force modernization leads to fewer resources for training and education.

2.3 ADL PROVIDES A MEANS FOR EFFICIENT AND EFFECTIVE CONTINUED LEARNING FOR THE TOTAL FORCE

The ADL initiative grew out of the DoD strategy to "harness the power of learning and information technologies to modernize education and training" (DUSD (R), 1999). ADL reflects Secretary of Defense William Cohen's vision of ensuring "that DoD personnel have access to the highest quality education and training that can be tailored to their needs and delivered cost effectively, anytime and anywhere" (DUSD (R) 1999). This initiative capitalizes on emerging network technologies to tie together distributed instructional resources, including intelligent tutors, subject matter experts, and traditional instruction to support "learner-centric" education on a continuing basis.

2.4 CURRENT ADL IS IN THE PROTOTYPE STAGE OF DEVELOPMENT

The initial implementation of ADL is yielding promising results, but the concept has still not received wide spread implementation. The reason, in part, is that the development of ADL courseware is in the "prototype stage," requiring experts to design and implement instructional programs. Scientifically valid principles for course design and commercial off the shelf software for authoring and are not available to support journeyman development of ADL material. Lack of standards regarding content format and underlying technology infrastructure further complicate ADL implementation. To significantly impact military training and education, ADL must develop a production model approach to development enabling rapid generation of tailorable and effective instruction.

2.5 DUSD (S&T) ESTABLISHED 2012 AS THE TARGET DATE FOR REALIZING THE PROMISE OF ADL

The DUSD (S&T) vision for ADL outlined in Figure 3 describes functional characteristics needed to enable robust cognitive capabilities. *"ADL in 2012"* will support the Total Force and contains six features:

- Accessibility: access instructional components from one remote location and deliver them to many other locations
- Interoperability: use instructional components developed in one location with one set of tools or platform in another location with a different set of tools or platform
- Adaptability: tailor instruction to individual and situational needs
- Reusability: incorporate instructional components into multiple applications
- Durability: operate instructional components when base technology changes, without redesign or recoding
- Affordability: increase learning effectiveness significantly while reducing time and costs (Parmentier, 1999)

"ADL in 2012" Characteristics

"ADL in 2012" will be a collaborative, affordable and adaptive instructional environment for the Department of Defense education and training. The environment will be interoperable, open and evolutionary, with a ubiquitous, distributed, standards-based infrastructure. *"ADL in 2012"* will have an integrated toolset to permit intelligent design guidance, continuous task analysis, learning and field performance assessment and feedback, cognitive task analysis, insertion and modification of practice components, and automatic upgrades of training and performance support content and strategies. Adaptable to characteristics of learners and teams, *"ADL in 2012"* will account for aptitude, diversity and culture, incoming skills and knowledge, and provide training and performance support anytime and anywhere for DoD missions. Individuals and teams will be supported by a system that promotes development of competencies such as collaboration, problem solving, analysis, evaluation, reasoning, critical thinking, and decision-making. They will be supported by an instructor and peer-based dynamic mentoring environment. *"ADL in 2012"* will be sustainable through a policy and institutional environment that adapts to fully support and embrace this vision.

(ADL S&T Workshop 1999)

Figure 2. The DUSD (S&T) _"ADL in 2012"_ Vision

2.6 THE CURRENT ADL S&T BASELINE

The current S&T effort reflects research addressing a number of ADL-related issues. These initiatives are focused on advancing the state-of-the art of instructional design and delivery to realize the robust ADL capability envisioned for 2012. The following programs represent the progress being made in applying an understanding of human cognition to computer aided instruction systems and simulations that are representative of the type of research needed to achieve the envisioned end state for *"ADL in 2012."*

- The Air Force's Crisis Action Planning Tutorial and Online Resource (CAPTOR) provides an example of the latest in computer aided instruction. This planning program uses theory-based curriculum planning to adjust instruction to reflect the learners' pace and previous performance. ***CAPTOR operates across the Internet and uses a standard point and click web interface.***

- The Navy's Interactive Multisensor Analysis Training (IMAT) system for its Anti-Submarine Warfare forces illustrates the potential of simulations for education and training. IMAT provides training and performance support from the schoolhouse where it is used to teach basic acoustic theory to the battle group where it assists in mission planning and analysis. The use of IMAT resulted in doubling instructor-trainee interaction, decreased academic setback/attrition, and a three standard deviation improvement in the performance of reasoning tasks (Wetzel-Smith and Wulfek, 1999). ***The simulations operational use validates its realism and suggests that other simulations can impact individual training and job performance.***

- The Department of Commerce's' Courseware Factory Associate (CFA) highlights a non-DoD advance in the development of authoring software needed for ADL generation. Scheduled for release in December 1999, CFA is a standards-based authoring tool that allows instructors to build lessons using tailored, intelligent design guidance. CFA provides automatic parsing of instructional material into tagged, reusable objects and contains tools to build adaptive learning environments. ***The result of this process will be computer aided instruction that suggests logical courses of action to solve problems and answer trainee questions about the domain.***

2.7 AN ADL S&T WORKSHOP PROVIDED EXPERT REVIEW OF THE FRONT-END ASSESSMENT

The front-end assessment defined the military necessity of ADL and provided the basis for the 4-day ADL S&T Workshop held in October 1999. The workshop was comprised of 69 experts in training and education, psychology, educational research, hardware and software development, and related areas. They represented each of the military Services, other government agencies, academia, and industry. Over 100 decision-makers and subject matter experts attended either the workshop or attendant briefs (See Appendix B).

2.8 THE ADL S&T WORKSHOP DEFINED KEY ELEMENTS OF THE *"ADL IN 2012"* RESEARCH AGENDA

During the course of the workshop, the participants identified research and development capabilities required to support anytime, anywhere learning for the Total Force through 2012. Each major capability was broken down into functional characteristics, which in turn were examined for specific technical challenges and associated research issues. This comprehensive process provided a level of detail and general consensus otherwise unreachable by the front-end assessment alone.

Post-workshop analysis organized these required capabilities into four research areas relevant to military education and training. These research areas address the educational design process from requirements analysis and course development to delivery and assessment.

- **Intelligent Computer Aided Instruction (ICAI):** ICAI focuses on the development of an empirical foundation of how individuals and teams develop expertise, guide the selection of ADL instructional alternatives, and provide accurate assessment to enable appropriate follow-on and remedial instruction.

- **Authoring Tools:** Authoring tools look at the development of tools to quickly and appropriately retrieve and apply digitally coded knowledge and skills to the development of intelligent tutors and embedded assessment.

- **Distributed Simulations:** Distributed simulations look at the problem of generating realistically performing models of individual behavior, virtual team members, adversaries, friendly forces, and non-combatants in a realistic environment.

- **Dynamic Learning Management (DLM):** DLM addresses the infrastructure architecture needed to ensure ADL interoperability and security.

SECTION 3
"ADL IN 2012": RESEARCH ASSESSMENT

The challenges for achieving "*ADL in 2012"* and the recommended programs of research are summarized at the end of this section in Table 3 (Table 2 provides the interpretation of the symbols used in Table 3). These challenges and the research initiatives needed to address these challenges are described further in this section. Each subsection presents a brief description of the R&D **Recommendation** followed by the **Challenges** that it addresses. The **Discussion** provides an explanation of how this recommendation fits with related challenges in the overall R&D effort to achieve the vision for "ADL in 2012". It is here that mention of similar programs is made but not dealt with in detail. The intent is both to confirm the relevance and importance of recommended efforts, and to demonstrate that the requirement has not already been addressed. A more detailed explanation of the recommended research is presented in the **Required Research**.

3.1 INTELLIGENT COMPUTER AIDED INSTRUCTION (ICAI)

3.1.1 Recommendation: Develop Robust ICAI Protocols That Facilitate ADL

ICAI development is crucial to achieving the vision of *"ADL in 2012."* DUSD (S&T) should support the development of robust ICAI for ADL based on knowledge models of human learning and performance for individuals and teams.

3.1.2 Challenge: Real World Constraints Define the Requirement for *"ADL in 2012"*

"ADL in 2012"

The instructor surveyed his class of noncommissioned officers present to receive instruction on hazard modeling as part of their training for the National Guard's Rapid Assessment Initial Detection teams. The background and experience of the class were uneven with several students having attended the Chemical School and others with minimal nuclear, biological, and chemical (NBC) training. The challenge was to bring the newcomers to NBC up to speed, while simultaneously furthering the expertise of the more seasoned students.

The integration of ICAI into the course design offered the solution. Intelligent tutors sensitive to learner needs and background aided the instructor in presenting the course material at a pace and sequence that the students could absorb. At the end of the week of instruction, all the students achieved the minimum proficiency required with many developing in-depth expertise.

The requirement to train and educate a less qualified and less experienced force is leading the Services to recast the focus of military education and training from the current one-size-fits-all approach to a more tailored and effective instrument (Abold, 1999). Instructors need to reach beyond the bell curve and challenge students at the extremes. The Services can no longer afford to lose candidates due to the inflexibility of the current military education and training system. Conversely, more capable learners must be challenged to reach their potential.

3.1.3 Discussion: Train and Educate a Less Experienced Force to Survive and Win on Future Battlefields

Advances in artificial intelligence and cognitive science during the past 20 years enabled research and development of ICAI systems. The development of knowledge representation techniques is enabling designers to move beyond the static instructional systems that characterized past computer assisted instruction (CAI). Earlier systems provided students little interaction with the instructional content, as they followed preprogrammed access to content, assessment, and feedback. Like effective CAI systems, emerging ICAI development includes careful task analysis, theory-based instructional manipulations, and empirical system refinements. The ICAI approach, however, uses information-processing models of cognition that are more precisely specified than earlier theories of learning. This, in turn, leads to the creation of cognitive engineering involving systems design procedures and technologies that capitalize on human information processing (IP) strengths and remediate against human IP weaknesses (Regian, 1999).

The impact of computer technology on learning is dramatic and holds the potential for even greater results. Using established methods, CAI routinely enhances learning by 0.3 to 0.4 standard deviations (sigma). This translates to an achievable 15 percent increase in learning over traditional methods; that is, an average (50^{th} percentile) student using CAI will score as well as an above average (65^{th} percentile) student in a traditional classroom environment. Alternatively, CAI can produce student performance comparable to traditional instruction, but in 24 percent less time. There are a variety of ways to enhance learning or reduce learning time, but CAI is proving among the most cost effective. Studies of intelligent CAI are even more promising, with an average effect of 1.00 sigma improvement, reflecting a 34 percent increase in learning, or a 55 percent reduction in learning time (Regian, 1999). Efficiency studies of ICAI suggest that cost will be similar to CAI (Regian, 1999). Additional savings will also be accrued from reductions in travel and time spent away from the job.

Ultimately, the goal of ICAI is to obtain the two sigma improvement in learning demonstrated by Bloom in one-on-one human tutoring (Bloom, 1984). More recent work indicates that machine tutoring can produce gains approaching the time consuming and expensive process of human tutoring (Fletcher, 1999). To achieve these results ICAI must duplicate the continuous assessment process (formative, ongoing, summative) inherent in traditional tutoring. The ability of the instructor to recognize student understanding and predict behavior is directly related to the selection of instructional approach and subsequent instructional effectiveness. *Understanding of learner's cognitive state* enables the instructor to choose corrective action that the student can process. Figure 5 illustrates the envisioned benefits of next generation technology in improving the learning process (Parmentier, 1999).

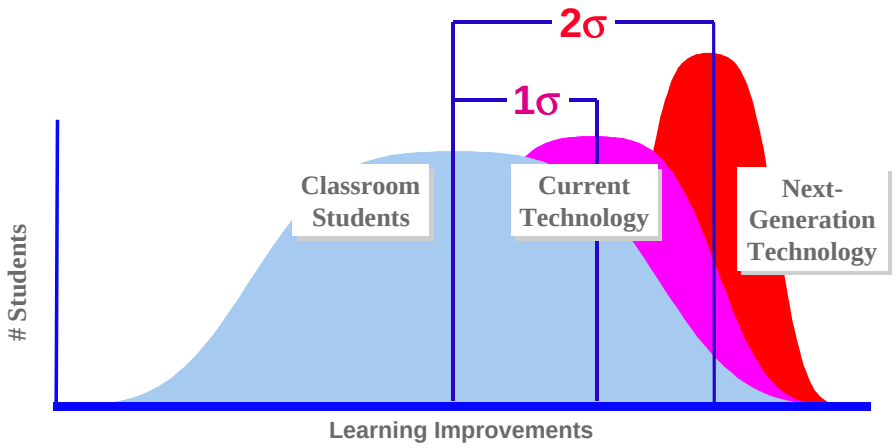

Figure 3. The Two Sigma Challenge (Bloom, 1984)

The application of Instructional Systems Design and second generation *intelligent tutoring* is impacting existing military training and education today. The Air Force's CAPTOR is an example of an intelligent tutoring system supporting decision-makers in planning and executing joint operations in a crisis. CAPTOR enables users to learn relevant information, including data on personnel, intelligence, operations, and logistics, in a self-paced environment.

Further insights into the process of *individual and team learning* are required for next generation military ICAI. Cognitive research has compiled a wealth of data regarding individual learner issues. Factors ranging from the learner's background and motivation to general intelligence are recognized components of sound course design. Less understood is the dynamic of team learning involving the interaction and collaboration of two or more individuals pursuing a common goal or outcome. Recent research (Salas, 1998) has been promising, demonstrating the possibility that some team training may be conducted using intelligent agents or tutors as "team members" (Macedonia, 1999).

The downing of an Iranian airbus in 1988 demonstrates what can happen when team processes break down under stress and exhaustion. It illustrates the need for future ICAI to address simple and complex tasks through the use of an assortment of instructional strategies. Researchers must be able to represent during training variables such as stress and exhaustion confronting military personnel as they conduct the intricate fast-paced operations involved in modern warfare. The development of expertise in these situations relies not just on accumulation of factual or declarative knowledge but on non-declarative components such as perception and attention. The ability to perform high-level pattern recognition by filtering out extraneous detail separates novices from experts (Kellman, 1999).

Accurate *assessment* techniques are an essential element of ICAI. To approximate the performance of a human tutor, ICAI must contain an embedded assessment function to ensure the acquisition and retention of the desired learning content. This assessment

capability must account for the learner's previous experience and personal capabilities in tailoring initial instructional material and design prior to the course. During the course, ICAI needs to be capable of identifying student weaknesses through accurate assessment and then providing appropriate remedial action. It is critical that this assessment process measure characteristics that translate to successful job performance.

Human-Computer Interfaces (HCI) comprise the final critical component in using ICAI. Deficiencies in HCI design create steep learning curves for students as they focus more on navigating the instructional system than on learning the content. The ability to engender natural two-way interaction between the ICAI and student flattens the learning curve as well as increasing the number and improving the quality of the interactions between the student and the instructional content.

3.1.4 Required Research Initiatives in ICAI for Enhanced Learning

The recommended program of research to develop effective, flexible ICAI by 2012 relies on investment in the following technologies and/or theories:

3.1.4.1 Cognitive Theory. The objective of this research thrust is the formation of a learning model built on an understanding of how individual and team expertise develops, and that tailors instruction to task requirements and learner characteristics. The research must:

- Define the evolution of expertise in complex, ill-structured environments
- Identify and exploit the relationship between domain-specific problem solving skills and generalizable strategies
- Develop the theoretical basis for accommodating cognitive workload as related to the intrinsic capability of the learner
- Determine the role and significance of flexible, adaptive learning in promoting better problem solving, and critical thinking
- Develop the theoretical basis for employing interactive simulation and training methodologies to guide the use of simulations
- Capture the effective behaviors of outstanding human instructors
- Account for the effects of stress and other psychological factors influencing the learner

3.1.4.2 Assessment. The objective of research on assessment is to increase the efficiency and validity of on-line assessment for individuals and teams through development of a performance-based dynamic model of learner assessment. This research requires the following:

- Develop technologies allowing free-form inputs for assessment
- Generate valid, unobtrusive near real time assessment information from learner interactions with the learning environment
- Develop comprehensive models and measures of individual and team capabilities and performance
- Integrate existing mission and occupational performance requirements

- Model individual training and experience histories to predict ease of learning and retention of needed task-specific knowledge and skills

3.1.4.3 Collaborative, Group, and Team Learning. The objective of this research is the development of mechanisms to enhance instructional effectiveness of learner-learner collaborations, learner-instructor interactions, and to promote team-building skills. The creation of collaborative instructional strategies requires researchers to:

- Define models for collaboration and interaction considering distance, content, role, capabilities, and task requirements
- Create and evaluate alternative collaboration arrangements and interaction strategies
- Develop team-level tutoring concepts

3.1.4.4 Intelligent Tutors. The objective of this research thrust is the development of intelligent tutors sensitive to relevant task and learner characteristics. This capability requires research to:

- Determine relevant task characteristics (e.g., complexity, domain, cognitive versus psychomotor) for instructional design and selection of instructional strategies
- Ascertain relevant individual characteristics (e.g., level of expertise, ability, motivation, and culture) for instructional design and selection of instructional strategies
- Determine interactions between task and individual characteristics
- Develop a tutor "presence" capability sensitive to curriculum, level of expertise required, and learner characteristics

3.1.4.5 Human-Computer Interfaces (HCI). The objective of HCI research is to employ optimal human-computer interfaces with intelligent tutors and performance support coaches, allowing unrestricted two-way dialog between the learner and the system. HCI includes the following:

- Develop models of effective human tutorial dialog
- Implement optimal instructional strategies and technical approaches to natural language understanding, generation, and dialog management
- Employ tools for authoring and modifying natural language dialog systems
- Develop hardware/displays for augmented reality systems

3.2 AUTHORING TOOLS

3.2.1 Recommendation: Develop ADL Authoring Tools to Support the Vision of *"ADL in 2012"*

DUSD (S&T) should support the development of tools, techniques, and technologies that assist in the cost-effective generation of tailored ADL learning and practice environments by 2012.

3.2.2 Challenge: Tailor Modalities in Near Real Time to More Fully Achieve Optimal Operational Performance

"ADL in 2012"

Increased tensions in the Balkans have led to yet another shift in focus for the battalion S-3. Instead of completing preparations for an upcoming field exercise in Germany, Major Jones, US Army, must prepare for a rapid deployment to Kosovo to support the peacekeeping mission. Major Jones' task is to develop detailed training material covering operations orders, local conditions, population demographics, information on the political situation, and available intelligence on potential adversaries.

To fulfill his orders, Major Jones relies on a suite of authoring tools to search relevant sources of information from DoD and civilian databases, parse the data, and assemble the information into a series of interactive training tools tailored to the needs of the battalion officers and enlisted leaders as well as individual soldiers. These tools include ICAI and simulations that walk the soldiers through their impending mission.

Speed, flexibility, and economy in training system design will improve operational performance. Additional ICAI and simulation tools are needed to prepare personnel for the missions they will face in the new millennium, but development time and cost considerations limit their employment. The Services must design systems, procedures, and technologies to develop affordable and tailored distributed learning to realize the potential of *"ADL in 2012*." Authoring tools which can build and integrate the appropriate level of artificial intelligence, use unobtrusive and accurate assessments based on an understanding of cognitive theory and the group and team learning process are essential to developing tailored, useful, and timely instructional programs.

3.2.3 Discussion: Rapid Acquisition of Information and Construction of Optimal Learning Curricula are Key to Building Effective Authoring Tools

The goal for *"ADL in 2012"* is the development of ICAI and simulations that improve performance, enable better use of human instructors, and reduce training time and costs. The previous section outlined the potential power of these tools in future ADL. Central to the concept of *"ADL in 2012"* is the ability of "journeyman" instructors to rapidly author and modify courseware and simulations. Courseware modification is required to allow instructors to make adjustments compensating for user feedback or changes in mission, equipment, or intended learners.

Knowledge representation technologies are providing improved methods to acquire, store, maintain, retrieve, and apply digitally coded human knowledge and skills (Regian, 1999). These technologies are enabling curriculum designers to leverage advances in the understanding of human perception, cognition, and action. *"ADL in 2012"* must support

the ability to perform the knowledge engineering (extraction and coding of human expert knowledge) and knowledge recoding (extraction and recoding of existing, knowledge-bearing digital data) necessary for efficient courseware authoring.

Fielding of ICAI programs is currently in the "prototype stage," reflecting a handcrafted approach to development that is too often domain specific (Sams, 1999). The knowledge representation technologies behind these systems are labor intensive and are typically not transferable from one subject to another (Regian, 1999). Vast stores of knowledge reside in proprietary databases and single use media such as text, pictures, and video. *"ADL in 2012"* will efficiently mine knowledge throughout the Services, from after action reports to information resident in computer assisted drawing and engineering systems. Management of these knowledge resources comprises a second part of the authoring equation. Without efficient knowledge storage and methods for retrieval from vast databases, instructors will be unable to rapidly configure instructional materials by marrying task-specific content to proven instructional strategies. Finally, *"ADL in 2012"* requires authoring tools that will facilitate the generation of ICAI based on a more thorough understanding of human cognition.

3.2.4 Required Research to Enable the Construction and Use of Authoring Tools

The recommended program of research for authoring tools contains two research thrusts that address the critical components of building expert systems: knowledge acquisition and rapid simulation and courseware development. These elements are enabling capabilities required for the realization of a robust ADL by 2012.

3.2.4.1 Knowledge Extraction. The objective of this research is to identify and extract required knowledge currently stored in static databases, embedded in system design, or possessed by subject matter experts to create dynamically reusable instruction material. The recommended research must:

- Develop intelligent search engines for parsing archived knowledge
- Develop database tools to ensure maintainability, reliability, and accessibility of data across generations of software utilized in the databases
- Develop intelligent search engines for quickly selecting, parsing, and reusing archived knowledge

3.2.4.2 Rapid Courseware and Simulation Development. The objective here is to develop readily composable knowledge objects capable of generating scenarios and courseware consistent with training, mission rehearsal, and real world deployment needs. The research must address the ability to:

- Develop tools, techniques, and methodologies to enable rapid development of learning centered simulations, ICAI and system management software
- Generate feedback of human and system performance data to a centralized human resource tracking facility

3.3 DISTRIBUTED SIMULATION ENVIRONMENTS

3.3.1 Recommendation: Develop Distributed Simulation Environments and Related Technology for *"ADL in 2012"*

Accurate learning and practice environments are key for implementing *"ADL in 2012*." Therefore, DUSD (S&T) should assist in the development of integrated simulation tools and technology to support ADL.

3.3.2 Challenge: Increasing Complexity of the Battlefield Requires More Simulation-based Learning to Improve Combat Performance

"ADL in 2012"

Time: 1930 Zulu
Location: Somewhere in the Indian Ocean aboard the *USS WASP*
SITREP: 22nd Marine Expeditionary Unit en route to global hot spot for peacekeeping mission.

Lance Corporal Smith pulls on a headset and goggles, and says, "Lance Corporal Smith; Start." A small computer in the passenger compartment immediately accesses files on its database, notes his ability level and learning preferences and generates a training simulation.

The simulation walks Smith through the countryside in his area of responsibility, familiarizing him with the terrain, meteorological conditions, and people he is likely to encounter. These data reflect the latest intelligence estimates to include population shifts resulting from the fighting in the northern regions of the country. The simulation also includes a number of likely scenarios querying him for decisions at critical points and illustrating the consequence of his decisions. Mistakes made in the conduct of the training are noted allowing for further teaching if necessary.

As Smith disembarks, he notes the nation he is now in is already familiar and has a basic idea of how to operate there. He is less stressed and more effective as a direct result of his recent training using simulation technologies.

Military use of simulations, from individual equipment items to conflict simulators, is a widely accepted part of training. Emerging and future simulation environments offer unique opportunities for interactive learning and maintaining individual and unit readiness in an effective and affordable manner. As computer and communications technologies mature, training simulations promise to become more cost-effective and useful. The crawl, walk, run model captures the current modeling and simulation integration philosophy where simulations are useful tools in teaching Service personnel basic individual and team skills before investing in live training opportunities (Compart, 1999). Simulations provide an opportunity to explore new methodologies, tactics, and equipment capabilities in a safe environment, while recording and analyzing detailed results.

The use of simulations has resulted in significant improvements in the transference of knowledge from the learning environment to the field. Simulations can provide students with a realistic worldview that facilitates the practical application of training and education. A better understanding of the processes that underlie learning in interactive

contexts is required to successfully exploit the potential for simulation-centered ADL. DoD must explore how human cognitive modeling can impact simulations and its applicability to a range of training and education requirements.

3.3.3 Discussion: Human and Organizational Behavior Replication are Key to Providing Flexible Simulations

In recent years, the DoD made significant progress in creating seamless, synthetic environments supporting acquisition, operational testing, training, and readiness. These synthetic environments include virtual (real person in a simulator represented in simulated battlespace), live (real person in a real weapon system represented in the simulated battlespace), and constructive (computer-driven representations in a simulated battlespace) representations of a battlespace. The transition from Distributed Interactive Simulation (DIS) to DoD's High Level Architecture (HLA) reflected a number of lessons learned, providing an architecture to support real time and non-real time operations and entity and aggregate-level simulations. The Army's Modular Semi-automated Forces (ModSAF), for example, offers a realistic terrain environment for geographically separated forces to conduct platform-level engagements.

ModSAF and similar tools provide valuable training but are reliant on instructor participation to create dynamic and realistic scenarios. The experience and style of the commander and his staff govern simulation results. In the absence of human involvement, ModSAF relies on simplistic rule sets to perform command and control functions. This inability to accurately represent command staffs and their communications is a limiting factor in the usefulness of these types of tools for training. The move to large-scale simulation exercises magnifies the need for the presence of realistic command staffs for virtual forces. However, providing the necessary human staffs can be prohibitively expensive and logistically cumbersome. The same operation and personnel tempo considerations that affect participation in live training apply to synthetic exercises.

"ADL in 2012" will rely on credible, consistent, and efficient large-scale distributed training system simulations that must better represent the human aspects of command, control, and communications (C^3). Future ADL simulations must incorporate models of individual human and collective behavior such that they are indistinguishable from the real actors in similar environmental contexts. This ability will enable the Services to perform more realistic constructive simulations by implementing an expert system without human involvement. The result will be unpredictable simulations that replicate the fog of war in information-poor and information-overload environments.

A second, more general, challenge is the development of technologies to facilitate the routine and rapid generation of affordable, tailorable ADL environments. The myriad tasks facing the military today require instructors and planners to rapidly develop scenarios for diverse training and mission requirements. Current development, as with other forms of computer assisted instruction, requires in-depth domain knowledge, programming expertise, long lead times, and significant investment of resources.

3.3.4 Required Research Initiatives in Distributed Simulations

The primary objective is to generate realistically performing models of individual behavior, virtual team members, adversaries, friendly forces, and non-combatants. A second objective is the fielding of realistically performing models of organizational behavior for $C^3$and large entities like non-governmental organizations.
Required research initiatives must:

- Enable synthetic characters to respond to verbal and non-verbal commands and actions
- Enable dynamic control of synthetic characters by instructors or intelligent tutors
- Facilitate the interchange of real and virtual team members to support anywhere, anytime training delivery
- Develop rapid and efficient processes for verification and validation of simulation environments
- Develop models for immersive training and education

3.4 DYNAMIC LEARNING MANAGEMENT (DLM)

3.4.1 Recommendation: Develop a Dynamic Learning Management System to Support the Full Functionality Envisioned for *"ADL in 2012"*

DUSD (S&T) should oversee the development of Dynamic Learning Management (DLM) initiatives to achieve an open, evolving, and learning technology environment. This approach must be based on a ubiquitous, distributed learning infrastructure that enables the dynamic composition of content and management of the *"ADL in 2012"* system.

3.4.2 Challenge: A Common Technological Infrastructure is Required to Leverage Learning Initiatives to Support *"ADL in 2012"*

"ADL in 2012"

Lieutenant Commander (LCDR) Davis, US Navy, is currently assigned to the US Embassy in Thailand. His next duty station is a joint staff billet in Washington DC. He is unable to leave his current job to exercise with the staff or attend required courses. He is, however, able to access the Internet and with it the wealth of instructional material available throughout DoD. Using an encrypted link, LCDR Davis participates remotely in exercises via video teleconferencing and simulations. His coursework is completed in Thailand and scored remotely. LCDR Davis is properly prepared and able to move on to his new assignment in a way that would not have been available to him a few years earlier, due to lack of training and teambuilding opportunities.

The DoD investment in distance education and training technology over the past decade represents a significant outlay of funds. Technology such as CD ROMs, video tapes, and satellite broadcasts are key enablers, allowing instructors to realize many of the benefits of distance education design and delivery. While securing the building blocks to support advanced distributed simulations and distributed learning initiatives, the Services may not have fully exploited the full potential of available technology. The Services' independent

pursuit of education and training strategies and supporting technologies created stovepiped education and training communities (Abold, 1999). The DoD strategic plan for ADL provides a common vision to leverage existing technology infrastructure and future investments.

As DoD looks to the next generation of education and training programs, it can no longer maintain differing information technology infrastructures. The Armed Forces need to establish standards for education and training technologies to realize cost savings and ensure interoperability for security, hardware, software, system management tools, learning objects, and knowledge engineering tools. Technology acquisition decisions made today will affect current education and training programs and shape the direction of follow-on initiatives.

With the commercial sector now leading many computer and telecommunications advances, the military Services can take advantage of private sector research and development to reach operational goals. DoD must adopt a strategy of working with industry and academia to set required standards and select the best approach and technology to satisfy DoD objectives for *"ADL in 2012*."

3.4.3 Discussion: Security, Reliability, and Access to Data are Key to DLM

The ability to dynamically and adaptively construct learning and practice environments across individual Learning Management Systems (LMS) is integral to the concept of *"ADL in 2012*." The authoring of distributed simulations and ICAI will be based on reusable, shareable learning components. Developments in knowledge representation technologies discussed in Section 3.3 pave the way for a cognitive engineering approach to content development. The ability to capture knowledge and make it available in a standard form for use in training and performance support systems enables instructors to offer tailored, "just in time" instruction based on student needs.

The trend toward greater interoperability in the commercial sector is leading to the establishment of common standards and protocols for learning applications and networks needed for *"ADL in 2012*." Web-based technology such as Extensible Markup Language, Document Object Model, and style sheets are providing innovative resources for the storage, retrieval, and manipulation of existing materials. Despite the emergence of baseline functional capabilities, the development of an integrated LMS to support the construction of complex learning content from multiple learning "object" repositories is lacking. Courseware and its learning components cannot be readily transferred from one system to another under the current architecture. Moreover, there exists limited capability to identify relevant knowledge because of the inability to create searchable content or media repositories across different LMS environments (Dodd, 1999).

Achieving the envisioned *"ADL in 2012"* end state requires an appropriate architecture and design of content repositories that allow for the aggregation and disaggregation of learning content distributed across multiple LMSs. This challenge goes beyond providing straight text and includes providing multi-sensory environments that are critical to effective learning. Additionally, instructors must face the question of content degradation,

as information becomes dated or irrelevant. Content validation becomes more complex as the learning environment becomes more complex.

Issues concerning data integrity and access also impact *"ADL in 2012."* Confidence in the system's ability to limit access to appropriate individuals will be a key consideration in the posting of content. Secure transfer of data across multiple networks and organizations is another challenge facing ADL. Finally, connectivity and bandwidth capabilities define the parameters of any proposed distributed learning system.

3.4.4 Required Research Initiatives in DLM

The recommended program of research for DLM contains two research efforts and focuses on the development of a common architectural model to ensure ADL interoperability and security.

3.4.4.1 Infrastructure Architecture. The objective of this research thrust is to create an ADL architectural reference model that defines knowledge base, dynamic learning management, and knowledge content transport. Research in this area must:

- Address the graceful degradation of learning content
- Create software development methodologies and ADL authoring systems
- Develop rapid, efficient processes and procedures for verification and validation of ADL knowledge
- Automate indexing and searching, extraction, and reading of existing knowledge bearing digital data
- Develop efficient methods of extracting/coding human expert knowledge

3.4.4.2 Security. The objective of this research is to provide a pervasive security policy and technical strategy that addresses pan-network and pan-organizational authentication and data access security that are transparent to the user. This research must deal with the following areas:

- Provide data security and protection transparently across multiple organizations
- Develop reliable usable identification, authentication, and authorization
- Manage restrictions of access to the network, and maintain the security between source and destination

3.5 SUMMARY OF *"ADL IN 2012"* RESEARCH OBJECTIVES

Table 3, below, summarizes the required *"ADL in 2012"* research objectives detailed in Sections 3.1 to 3.4. The table is organized around the major research areas identified by the ADL S&T workshop (ICAI, Authoring Tools, Distributed Simulation, and DLM) and includes a brief description of the underlying functional objectives and associated research issues. These research issues represent the key technologies to reach the envisioned end state for *"ADL in 2012"* but have not been prioritized for research and implementation.

The "Research Status" block on the far right of Table 3 reflects the status of current research progress for each research issue in achieving the results necessary to achieve the overall *"ADL in 2012"* end state. Table 2 provides an explanation of the "stop light" symbols used in the "Research Status" block. These assessments are based on a review of current research efforts in the designated area, as well as an appraisal of developments in similar fields by industry, government, and academia. Where relevant, the track record of specific technology developments was factored into the final status determination. Finally, consideration was paid to the sequencing of research issues needed to ensure timely completion of the research required to reach the vision for *"ADL in 2012."*

The designation of a "green light" for *"Develop hardware and associated displays for augmented reality systems"* on the top part of page 22 is illustrative of the assessment process. Existing systems, such as the virtual reality worktable used for the Sea Dragon command and control project, are expensive and limited in their application. However, the pace of development in military systems over the last four years and the attention given by the gaming industry suggest that the requisite technology will be in place by 2012. A similar rationale was applied to the difficult task of *"Manage restrictions of access to the network and maintain the security between source and destination"* on the lower portion of page 24. The commercial interests in this field assure that resources from a number of sectors will be directed to research and development independent of the active involvement and participation of the DoD S&T community.

Conversely, there is no immediate commercial gain from or DoD program to *"Generate valid, unobtrusive near real time assessment from learner interactions with the learning environment"* on the top part of page 22. There is no track record of similar research to compare it to (given the complex character of this task, including software development, the role of artificial intelligence, and the general difficulty of assessment), and no indication that academia is pursuing this subject in an organized fashion. The confidence level that this subject will be addressed in a timely fashion is low, thus warranting the awarding of a "red light" and the recommendation for active DoD-sponsored research in this area.

Table 2. Advanced Distributed Learning Research Objectives Legend

Research Status Legend*	
	* These generalizations represent an assessment of the pace of research in these areas in the recent past, the current level of effort being expended by government, academia and industry, and an estimate of future progress by researchers in the cited areas if DUSD (S&T) provides no active management and direction to address the identified research issue.
R	Insufficient current and/or anticipated research progress addressing this Research Issue. This issue requires DUSD (S&T) active management and greater DoD investment to achieve the envisioned end state for *"ADL in 2012."*
Y	Borderline current and/or anticipated research progress addressing this Research Issue. This issue requires regular DUSD (S&T) review and occasional direction of research efforts to achieve the envisioned end state for *"ADL in 2012."*
G	Satisfactory current and/or anticipated research progress addressing this Research Issue. This issue suggests regular DUSD (S&T) review to monitor the pace of progress but no active direction is anticipated to achieve the envisioned end state for *"ADL in 2012."*

Table 3. Advanced Distributed Learning Research Objectives

(a) Intelligent Computer Aided Instruction			
Description	**Goals**	**Research Issues**	**Research Status**
Cognitive Theory Understand higher-order cognitive skill development including decision-making, problem-solving, metacognition, pattern recognition, critical thinking, situational awareness, and teamwork	Establish principles of distributed instruction based on established models of learning and skill acquisition Design ADL instructional alternatives built on understanding how individual and team expertise develops	Understand the evolution of expertise in complex, ill-structured environments Investigate domain-specific problem-solving skills and generalizable strategies Determine the role and significance of flexible and adaptive learning in promoting better problem solving, and critical thinking Capture effective behaviors of outstanding human instructors Develop theoretical basis for employing interactive simulations and associated training methodologies to guide use of simulations Develop an understanding of the role of interaction and collaboration in learning Develop techniques for assessing cognitive workload and strategies for mitigating adverse effects of workload	R Y R G Y Y Y

(a) Intelligent Computer Aided Instruction			
Description	**Goals**	**Research Issues**	**Research Status**
Assessment Link instructional assessment to field performance Develop methods for automatically generating assessment techniques Unobtrusive, near real time assessment	Develop a comprehensive model linking learner behaviors with learning and outcomes Increase the efficiency and validity of assessment generation Tailor assessment generation to individuals and teams Develop cumulative measures of relevant experience	Develop technologies allowing free form inputs for assessment Generate valid, unobtrusive near real time assessment from learner interactions with the learning environment Develop comprehensive models and measures of individual and team capabilities and performance Integrate existing mission and occupational performance requirements Model individual training and experience histories to predict ease of learning and retention of needed task-specific knowledge and skills	Y R R Y R
Collaborative, Group and Team Learning Create strategies for collaboration and interaction in ADL systems to enhance instructional effectiveness and increase the accessibility and speed of knowledge transfer Understand higher order cognitive skill development in teamwork	Establish principles of distributed instruction based on established models of learning and skill acquisition Develop mechanisms to foster optimal learner-to-learner collaboration and learner-to-instructor interaction Discover adaptive tutoring strategies for team-level tasks	Define models for collaboration and interaction considering distance, content, roles, capabilities and task requirements Create and evaluate alternative collaboration arrangements and interaction strategies Develop team-level tutoring concepts	Y G Y
Intelligent Tutoring Develop a robust ADL intelligent tutoring capability that enables better use of human instructors, reduces training time, and provides greater access to instructional resources	Build fully integrated intelligent tutoring capabilities for simple and complex tasks using a variety of instructional strategies Design adaptive tutoring strategies for team-level tasks	Determine relevant task characteristics (e.g., complexity, domain, cognitive versus psychomotor) for instructional design and selection of instructional strategies Ascertain relevant individual characteristics (e.g., level of expertise, ability, motivation, and culture) for instructional design and selection of instructional strategies Examine interactions between task and individual characteristics Develop a tutoring capability sensitive to curriculum, level of expertise required, and the learner's motivation, ability, and preparation	Y G Y Y

(a) Intelligent Computer Aided Instruction

Description	Goals	Research Issues	Research Status
Human-Computer Interface Employ natural language (NL) dialog with training systems, including intelligent tutors and performance support coaches Explore the potential for augmented reality to provide true anytime, anywhere training	Generate ability for full, natural communication with training and performance support systems Direct attention to relevant simulation features in a non-confusing, non-interfering way Explore augmented reality technologies; may provide a new level of context-specific training	Model effective human tutorial dialog Discover optimal instructional strategies and technical approaches to NL understanding, generation, and dialog management Build tools for authoring and modifying NL dialog systems Develop hardware and associated displays for augmented reality systems	G Y Y G

(b) Authoring Tools

Description	Goals	Research Issues	Research Status
Employ authoring tools to quickly build programs for instruction, human and system performance assessment, remediation, and support over local, wide-area, and global networks	Build authoring tools for courseware (individual and team, local and distance), artificial intelligence and assessment Allow rapid reconfigurability of instructional materials (scenarios, problems, cases, exercises) in accordance with task requirements Create tools for planning, deploying, and lifecycle management of courseware over networks Provide for ongoing empirical improvement of training and job-aiding	Create authoring tools for curriculum, simulations, assessment, system management, and intelligent tutors Provide automated feedback of individual and system performance data to centralized facilities Develop reusable components of ICAI and performance coaches Develop intelligent search engines for quickly selecting, parsing, and reusing archived knowledge	Y G Y Y

(c) Distributed Simulation Environments for Instruction

Description	Goals	Research Issues	Research Status
Technologies to enable the routine and rapid development of affordable, tailorable ADL environments that are robust and reliable Integrated architecture to support modeling individual human and organizational behavior	Build readily composable simulations to support the full range of education and training requirements Rapidly generate scenarios consistent with mission rehearsal and deployment needs Build realistically performing models of individual behavior for virtual team members, adversaries, friendly forces, non-combatants, and organizational behavior for command and control, and non-governmental organizations	Develop rapid, efficient processes and procedures for Verification and Validation of ADL environments Enable synthetic characters to respond to verbal and non-verbal commands and actions Enable the dynamic control of synthetic characters by instructors or intelligent tutors Enable the interchange of real and virtual team members to support anywhere/anytime training delivery Develop models for immersive training and education	Y Y G G Y

(d) Dynamic Learning Management (DLM)

Description	Goals	Research Issues	Research Status
A pervasive security policy and technical strategy that address pan-network, pan-organizational, authentication and data access and security An architectural reference model that defines knowledge base, dynamic learning management, and knowledge content transport Efficient knowledge acquisition, storage, maintenance, retrieval, and application of knowledge bases An engineering technology for efficiently capturing knowledge and task demands (cognitive, perceptual, and motor)	Enable secure access Use knowledge now stored in static databases or buried in system designs to create dynamic distributable instruction Establish a common format for acquisition, storage, maintenance, retrieval, and application of knowledge bases Create decomposable, reconfigurable, and shareable knowledge objects Describe well defined processes for cognitive task analysis including standard output formats	Develop reliable learner/user identification, authentication, and authorization Manage restrictions of access to the network and maintain security between source and destination Provide data security protection *transparently* across multiple networks and organizations Automated indexing and searching, extraction and recoding of existing, knowledge-bearing digital data Efficient methods for extracting and coding human expert knowledge Learning content aggregation and disaggregation Address graceful degradation of learning content High bandwidth ubiquitous network	G G G Y Y G Y G

SECTION 4
ADL POLICY AND CULTURAL ISSUES

Achieving the envisioned "*ADL in 2012"* capability presents a number of research questions for the science and technology community. Not all the challenges, however, are technical in nature. Policy and cultural change are needed to achieve the *"ADL in 2012*" vision. The last decade laid a first generation technical foundation for a revolution in education and training. This initial revolution gave us "distance learning," which has largely been accommodated within existing DoD policy and culture. Achieving the envisioned 2012 end-state presents DoD with several related key policy and cultural issues. Foundation for these necessary policy changes still needs to be put in place. Improving military readiness and performance and achieving the significant savings anticipated by using ADL technologies will require changes across the spectrum of the military Services.

Table 4 reflects a number of policy and cultural issues influencing the realization of the *"ADL in 2012"* vision of "A readily available instructional environment to support anytime, anyplace, anyone, anything learning" (ADL S&T Workshop, 1999).

Table 4. ADL Policy and Cultural Issues

ADL Generated Change	Policy and Cultural Issues
Opportunities will expand beyond the traditional classroom	Incorporate learning into every duty day in the same fashion as some Services do physical training
ADL will create "learner centric" military training and education	Accommodate the evolution of teaching from traditional instruction to mentoring
Joint training will become commonplace as will combined training with allies	Determine the desired level of technical interoperability with allies
Assessment will become an integral part of all training and educational activities	Overcome the negative effects on morale by carefully mapping assessment to field requirements
Assessment can be used to predict success or failure	Safeguard against the inappropriate use of predictive assessment
Not all relevant data will be ADL compliant	Commit to digitizing and storing critical historical information
ADL technology infrastructure will require a substantial capital outlay for development and maintenance	Enpower a programmatic champion to implement and maintain ADL infrastructure
ADL will affect all aspects of military training and education	Account for the differences between the Services' size, organization, mission, and traditions in implementing ADL
ADL will require a common set of standards and practices	Designate a controlling authority to oversee legal and logistical questions regarding interoperability and security

SECTION 5
RECOMMENDATIONS FOR *"ADL IN 2012"*

5.1 RECOMMENDATIONS FOR FOCUS OF S&T INVESTMENT TO ACHIEVE THE DESIRED END STATE FOR *"ADL IN 2012"*

The recommended programs of research offer a strategic plan to accelerate large-scale development of dynamic and cost-effective learning systems (e.g., ICAI and simulations), authoring tools, and supporting infrastructure to improve the cognitive readiness of the Total Force. This assessment offers research guidance to achieve the five elements outlined in the 1999 ODUSD(R) report to Congress dealing with:

- Common industry standards;
- Interoperable tools and content;
- A robust and dynamic network infrastructure for distribution;
- Supporting resources; and,
- Culture change at all levels of command, recognizing that learning is an official requirement of the duty day. (DUSD (R), 1999)

As the ADL 2012 S&T workshop demonstrated, the research areas are highly interdependent, with success in one sphere affecting advances in another. However, the DUSD (S&T) workshop and research assessment identified two key research issues that may impact the pace and direction of *"ADL in 2012"* implementation in the near term. In addition, the assessment recommends several steps by DUSD (S&T) to facilitate the prescribed *"ADL in 2012"* end state.

5.1.1 Understanding Human Cognition Provides the Basis for *"ADL in 2012"*

Understanding human cognition forms the basis for developing effective learning and practice environments for ADL. Cognitive theory defines the upper bounds of learning ability and provides a theoretical framework for how to achieve optimal results. Answers to basic cognitive research questions will provide designers and researchers a more robust framework to perform content engineering for ICAI and distributed simulations.

Research should be directed to:

- ***Understand the evolution of expertise in complex, ill-structured environments***
- ***Determine the role/significance of flexible/adaptive learning in promoting better problem solving and critical thinking***

5.1.2 Performance Assessment is the Key Enabler in Realizing *"ADL in 2012"*

Performance assessment is a second critical aspect for achieving the *"ADL in 2012"* vision. Accurate evaluation of various types of learning as measured against performance in the field is necessary so standards of skill attainment and effective instructional methodologies can be established (Brannick, 1997). Current assessment is usually based on arbitrary standards, relevant only in the organization doing the assessment. The ability for ADL to generate automatic and unobtrusive assessment techniques relevant to real world performance is necessary for timely instructor/system intervention, selection of appropriate remedial action, and learner motivation.

Research should be directed to:

- ***Develop valid, unobtrusive near real time assessment from learner interactions with the learning environment***
- ***Build comprehensive models and measures of individual and team capabilities and performance***
- ***Model individual training and experience histories to predict ease of learning and retention of needed task-specific knowledge and skills***

5.2 AN APPROPRIATE TECHNICAL INFRASTRUCTURE WILL ENABLE *"ADL IN 2012"*

Underlying the *"ADL in 2012"* vision is the assumption of an appropriate infrastructure that will support distributed learning. This infrastructure is essential to transform current ADL into an affordable and ubiquitous program. The development of an open, standards based system is required to link multiple independent learning systems and their content into a central dynamic learning management system. This system must support instructors and learners with built-in authoring tools that will provide intelligent design guidance and routine cognitive task analysis. The *"ADL in 2012"* support infrastructure must also enable sophisticated assessment and feedback to instructors. This will allow insertion and modification of practice components and automatic upgrades of training and performance support.

Development and installation of this technology infrastructure is independent of *"ADL in 2012"* but requires aggressive management to ensure this key enabler supports its implementation.

To ensure long-term success, DUSD (S&T) should appoint an organizational advocate with clear funding lines to oversee ADL infrastructure and methodology development.

5.3 AN INSTITUTIONAL ADVOCATE IS NECESSARY TO ACHIEVE *"ADL IN 2012"*

The problems of fragmented research and development facing ADL are analogous to those faced several years ago by the modeling and simulation community. The Defense Modeling and Simulation Organization (DMSO) was established to facilitate communication and coordination between researchers and organizations. A similar organization would lend weight to essential *"ADL in 2012"* education and training research, providing advocacy for required research areas currently lacking a sponsor.

Establishment of a DMSO-like organization would provide a central point of contact for ADL researchers and host regular workshops to provide opportunities for communications across and between interested communities. This organization would maintain close ties to ADL implementers in the Services, DoD, academia, and industry, ensuring that new techniques and pertinent research are garnered and shared across communities.

DUSD (S&T) should support the creation of an ADL training and education research organization to:

- ***Convene expert panels in cognitive theory and educational and training assessment to identify specific research issues in detail, and identify possible sources of that research***
- ***Conduct workshops to establish an R&D timeline for the identified critical issues through 2012***
- ***Oversee that required research is completed in a timely manner to arrive at the "ADL in 2012" goal***

5.4 ADVANCED CONCEPT TECHNOLOGY DEMONSTRATIONS WILL EXPEDITE THE INTRODUCTION OF *"ADL IN 2012"* TECHNOLOGY INTO THE TOTAL FORCE

In developing *"ADL in 2012"* technology, DUSD (S&T) must remain focused on addressing the instructional and performance support needs of the Total Force. At every opportunity mature technologies should be placed in the user community to allow for testing, evaluation, and operator feedback. Advanced Concept Technology Demonstrations (ACTDs) provide DUSD (S&T) a proven method for accelerating the introduction of mature or nearly mature technologies into the Force at a reduced cost. ACTDs prepare the transition of technologies from development to acquisition, addressing issues involving interoperability, life cycle cost, manning, training, and preparations for supportability.

An ACTD addressing C^4I would provide for the large-scale integration of *ICAI systems* based on the latest theoretical understanding of *cognition* and *embedded assessment*. This demonstration of ADL technology would allow the Services to develop new concepts of operations prior to entering the acquisition process. A second ACTD would provide for development of *authoring tools* and the required *infrastructure*. The designation of a principal sponsor for this ACTD would provide the management oversight critical to the implementation of *"ADL in 2012*." An institutional advocate would address many of the policy and cultural issues associated with ADL.

Together, these two ACTDs would cover the gamut of research issues from bandwidth to Human-Computer interfaces, providing DUSD (S&T) a starting place to monitor the state-of-the-art, provide the Services with additional capability, and accelerate development of *"ADL in 2012"* overall.

DUSD (S&T) should support meaningful demonstrations of "ADL in 2012", develop and test concepts of operations to optimize instructional effectiveness, and prepare to transition "ADL in 2012" technology into the formal acquisition process.

5.5 THE NEXT STEPS

Supporting the human cognition and performance assessment research initiatives (recommended above) and monitoring the other research outlined previously (see Section 3) will enable DUSD (S&T) to develop and manage an ADL research plan to achieve the envisioned end state for *"ADL in 2012."* The **immediate action steps** to work toward this desired goal efficiently include:

- Convene panels of experts in the areas of Intelligent Computer Aided Instruction, Authoring Tools, and Distributed Simulations to define the current state-of-the-art in the identified areas and subareas. (While this assessment has pointed out some significant state-of-the-art examples (see Section 2.6), these examples are neither sufficiently inclusive nor comprehensive enough to define the state-of-the-art in ADL). These experts should represent a cross-section of leading workers from the DoD and the Military Services, other government agencies, industry, and academia in their respective fields.
- Task these panels to identify key milestones needed to achieve the *"ADL in 2012"* envisioned end state, in addition to defining the state-of-the-art.
- Develop a set of research roadmaps for each area and subarea based on the definition of the beginning and end states as well as key milestones along the way. Coordinate these roadmaps with each other to remove unnecessary redundancies and to ensure that they are sufficiently comprehensive and mutually supporting. (When appropriately funded, this set of roadmaps provides an initial research agenda that supports the ADL Strategic Plan.)
- In parallel, identify the institutional advocate (Section 5.3) to direct the work of these expert panels, develop and coordinate the initial research agenda, interface with the ADL research community, and work to ensure appropriate funding levels to carry out the recommended research initiatives.
- In parallel, task an appropriate organization to monitor infrastructure developments with the intent of ensuring that those critical research areas identified as Dynamic Learning Management (see Section 3.4) make appropriate progress independent of active management from the ADL community. This organization should also ensure that the infrastructure development agencies recognize the ADL community as a "user" of the technology infrastructure they are developing.

Taking this "immediate action" and aggressively pursuing the recommended research initiatives will set the stage for accomplishing the goal of achieving the envisioned end state for "*ADL in 2012."*

GLOSSARY OF TERMS

ACTD	Advanced Concept Technology Demonstration
ADL	Advanced Distributed Learning
CAPTOR	Crisis Action Planning Tutorial and Online Resource
C^3I	Command, Control, Communications, and Intelligence
C^4I	Command, Control, Communications, Computer, and Intelligence
CFA	Courseware Factory Associate
DLM	Dynamic Learning Management
DMSO	Defense Modeling and Simulation Organization
DoD	Department of Defense
DUSD (R)	Deputy Under Secretary of Defense Readiness
DUSD (S&T)	Deputy Under Secretary of Defense Science and Technology
HCI	Human Computer Interface
ICAI	Intelligent Computer Aided Instruction
IMAT	Interactive Multisensor Analysis Training
IP	Information Processing
LMS	Learning Management System
NBC	Nuclear, Biological, and Chemical
RMA	Revolution in Military Affairs
RRDS	Research and Development Descriptive Summaries
S&T	Science and Technology

REFERENCES

ADL S&T Workshop, 1999

Abold, P., (1998), MORS SIMTECH 2000 Training and Education Panel Brief.

Bloom, B.S., (1984), The 2 Sigma Problem: The Search for Methods of Group Instruction as Effective as One-to-One Tutoring. *Educational Researcher*, June/July, 1984, pp. 4-16.

Brannick, M., Salas, E., Prince, C., (1997), Team Performance, Assessment and Measurement; Theory, Methods and Applications Lawrence Erlbaum Associates, New Jersey.

Compart, A., (1999), Virtual Combat, *National Guard*, p42, September, 1999.

Dodds, P. (1999), ADL Shareable Courseware Object Reference Model, Brief at ADL S&T Workshop.

DUSD (R), (1999) Department of Defense Strategic Plan for Advanced Distributed Learning

Dwyer, D.J., Oser, R.L. and Salas, E., (1999, in press), Performance Measurement in Distributed Environments: Initial Results and Implications for Training, *Military Psychology*, In press.

Fletcher, J.D., (1997), What Have We Learned About Computer Based Instruction In Military Training? *Virtual Reality, Trainings' Future?* Plenum Press, New York.

Hoffman, F. G., (1994), Training 2001 *Marine Corps Gazette*, p14, July 1994.

Holz, R.F., Hiller, J.H., McFann, H.H., (1994), Determinants of Effective Unit Performance, Research on Measuring and Managing Unit Training Readiness, US Army Research Institute for the Behavioral and Social Sciences.

Jacobstein, N., and Sams, M. (December, 1998), ADLI R&D Roadmap, ADL S&T Workshop.

Joint Vision 2010, 1996.

Kellman, P., (1999) E-mail comments from the Director, UCLA Cognitive Science Research Program

Krulak, C., (1999), The Strategic Corporal: Leadership in the Three Block War Marines, January 1999.

Macedonia, M., (1999), 21st Century ADL, Brief at ADL 2012 workshop.

Myers, S. Drop in Recruits Pushes Pentagon to New Strategy, *New York Times*, newspaper, September 27, 1999.

Parmentier, M. A., (1999), A Vision of the Future Learning Environment, Brief at ADL S&T workshop.

Regian, W., (1999), CAPTOR: Crisis Action Planning Tutorial and Online Resource Brief, at ADL S&T Workshop.

Tracey, P., (1999), Cognitive Readiness: Science and Technology Brief, at ADL S&T Workshop.

Wetzel-Smith, S.K., and Wulfeck, W.H. (1999), Interactive Multisensor Analysis Training Brief, at ADL S&T Workshop.